EFFECT OF TWO SUSPENDED PARTICLE IN SUPERPOSED VISCO-ELASTIC (Walter B') FLUIDS THROUGH A POROUS MEDIUM

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ABSTRACT

In present paper we considered two suspended particle in superposed viscous-elastic (Walter B') fluids through porous medium. Here, a horizontal barrier divides the two uniform Walter B' fluids. With the help of equation of continuity and equation of motion we derive the perturbation equations. Examine the viscous and visco elastic (Walters B`) fluids, separated by a horizontal boundary. In exponentially varying density cases, the system is shown to be either stable or unstable depending on the circumstances for the stable configuration. As a result of the unstable arrangement, the system is unstable. Similar results are obtained for the situation of an exponentially variable density in stable stratification, however the system is found to be unstable for the unstable stratification. With the aid of the MATLAB App, the analytical and graphical characteristics of growth rates with respect to fluid viscosity, viscoelasticity, suspended particle number density, medium permeability, fluid density, and drag coefficient are evaluated.

KEYWORDS: Rayleigh-Taylor instability, suspended particle, viscous-elastic fluid, porous medium, permeability.

1. INTRODUCTION:

Many authors had published their study and practical on viscoelastic fluid and their results, motivate for next research. Some of them are discussed here. Archana Shukla[1] investigated on Thermosolutal Instability in Walters B` Viscoelastic Fluid Permeated withsuspended particles in Porous Medium in 2019. Dixit Yogesh (2010)[11] conducted research. He found that Couple-stress fluid exhibits Rayleigh- Taylor instability in the presence of suspended particles in a porous media. while Rayleih- Taylor instability of viscous-viscoelastic fluid via porous material in presence of suspended particles was explored by B. A. Toms and D.J. Strawbridge[3]. The stability of two superposed Walters B viscoelastic fluids that diffuse via suspended particles in porous media was studied by Pradeep Kumar (2000)[12]. In 2001, Kumar and Sharma [8] had examined "Stability of superposed visco- elastic fluids in the presence of suspended particles through porous medium." Dusty elastic-viscous Rivlin-Ericksen fluid was the subject of research by R.K. Srivastava and K.K. Singh[5]. In their work, they used channels with various cross-sections in the presence of a time-dependent pressure gradient and unsteady flow. Additionally, Thermal Convection in Rivlin-Ericksen Elastic-Viscous Fluid in Porous Medium in Hydromagnetics was studied by R. C. Sharma and S. K. Kango[7]. A paper titled "Thermal Instability of Fluid through a Porous Medium in the Presence of Suspended Particles, Rotational and Solute Gradiant" was written by R.C. Sharma and K.N. Sharma[6] and published in 1982. The issue is useful in a number of geophysical and chemical technology contexts.

The equilibrium properties of an incompressible heavy fluid with varying density are used to derive the Rayleigh- Taylor Instability, a type of instability equation. We consider two

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significant exceptional situations in this sort of instability. (a) A fluid with continuous density stratification; (b) two fluids superposed with varying densities. Chandrasekhar [2] had studied this instability for non-porous medium and give important results. The flow through porous media is of great interest to geophysical fluid dynamicists and petroleum engineers in this kind of issue Lapwood [13] also studies the stability of convective flow in hydrodynamics in a porous medium using the Rayleigh technique. Wooding [14] had taken into account the Rayleigh instability of a thermal boundary layer in flow through a porous medium. In geophysical conditions, the fluid may alternately be infiltrated by suspended particles and is hence not pure. Scanlon and Segel [15] explored how suspended particles affected the start of Benard convection. They discovered that the critical Rayleigh number was only decreased because the particles supplemented the pure gas's heat capacity. T. Dixit and Yogesh Dixit [9] released a study on the topic of the Hall Effect on Thermosolutal Instability of Couple Stress Fluid with Suspended Particles in Porous Medium. When Sharma and Sharma [16] studied the thermal instability of fluids in a porous media in the presence of suspended particles, they discovered that the suspended particles and the medium's permeability had destabilised the layer. The most crucial part of Darcy's law was presented. When liquid slowly percolates through the rock pores, the gross impact is depicted in Darcy Law. In all the above studies the fluid has been considered to be Newtonian. Given the expanding significance of contemporary technologies and industries, research into non-Newtonian fluids is desirable. Oldroyd [16] provided theoretical models for a group of viscoelastic fluids. The methyl methacrylate (dilute) solution in n-butyl acetate, according to Strawbridge and Tom [17], aggress well with the Oldroyd fluid theoretical model. Regarding the Rayleigh- Taylor instability of a Newtonian viscous fluid including suspended particles in a porous medium, Kumar [19] also conducted research on an Oldroydian viscoelastic fluid. In his research on an Oldroydian viscoelastic fluid, Kumar (19) also took into account the Rayleigh- Taylor instability of a Newtonian viscous fluid with suspended particles in a porous medium. Pardeep Kumar[23] published a research paper on Stability of Two Superposed Viscoelastic (Walters B') Fluid-Particle Mixtures in Porous Medium in 1998. Sharma and Kumar [20] studied an Oldroydian viscoelastic fluid in 1996 in order to determine whether it was thermally unstable in a porous media. They also took uniform rotation into account. Walters B' is one class of elastic-viscous fluids that cannot be described by Oldroyd's [16] constitutive relations. Archana Shukla[24] investigated on unsteady hydromagnetic free convective flow and mass transfer of an eastico-viscous fluid past an infinite vertical porous plate in a rotating porous medium in 2020. Sharma and Kumar [21] studied the stability of the two viscoelastic (Walters B') superposed fluids of uniform densities by plane interface in 1997. These kinds of elastic-viscous fluids are employed in the analysis of the stability of two superposed Walters B' viscoelastic fluids penetrated with suspended particles in porous media. The importance of the viscoelastic fluid-particle mixes in terms of science and industry is not equal.

This study could be used to some polymer solutions, and it has application in geophysical and chemical technologies.

2. PERTURBATION EQUATIONS

We take horizontally arranged suspended particles in a static state of an incompressible two superposed visco-elastic fluids. Let gravity force = $\overline{g}$`$(0,0,-g)$, ρ = density, p = pressure, μ = viscosity, μ` = viscoelastisity, v(u,v,w) = velocity of fluid, q_d(a,b,c) = velocity of particle, m = mass of particle and Ñ (X,t) = number density of the particle. The equation of motion and continuity for two superposed fluids is given by if X = (x, y, z) and ϵ is the medium porosity,

ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 11, Iss 11, 2022

$$\frac{\rho}{\epsilon}\left[\frac{\partial v}{\partial t}+\frac{1}{\epsilon}(v.\nabla).v\right]=-\nabla p+\rho\bar{g}+?\nabla^2 v-\frac{1}{k`}\left(\mu+\mu`\frac{\partial}{\partial t}\right)v+\frac{K\tilde{N}}{\epsilon}(q_d-v) \quad (1)$$

And $\nabla.v=0$ (2)

K = 6πμR, is referred to as the stokes drag coefficient in this equation, and R is the particle's radius.

Since the fluid under consideration cannot be compressed, its particle density is constant.

So from equation of motion, we have

$$\epsilon\frac{\partial\rho}{\partial t}+(v.\nabla)\rho=0 \quad (3)$$

$$m\tilde{N}\left[\frac{\partial q_d}{\partial t}+\frac{1}{\epsilon}(q_d.\nabla)q_d\right]=K\tilde{N}(v-q_d) \quad (4)$$

and

$$\epsilon\frac{\partial\rho}{\partial t}+\nabla.(\tilde{N}q_d)=0 \quad (5)$$

In initial state,

v = (0, 0, 0), q_d = (0,0,0) and Ñ= N_0 is a constant (uniform particle distribution). For calculation of equilibrium we assume that the system is slightly disturbed. Let $\delta\rho = density, \delta p = prssure, v(u,v,w) = velocity\ of\ fluid\ and\ q_d\ (a,b,c) =$ particle velocity. Then equations (1) to (5) changed as

$$\frac{\rho}{\epsilon}\frac{\partial v}{\partial t}=-\nabla\delta p+\bar{g}\delta\rho+\mu\nabla^2 v-\frac{1}{k`}\left(\mu+\mu`\frac{\partial}{\partial t}\right)v+\frac{K\tilde{N}}{\epsilon}(q_d-v) \quad (6)$$

$$\nabla.v=0 \quad (7)$$

$$\in\frac{\partial}{\partial t}(\delta\rho)=-w(D\rho) \quad (8)$$

$$\left(\frac{m}{K}\frac{\partial}{\partial t}+1\right)q_d=v \quad (9)$$

$$\frac{\partial M}{\partial t}+\nabla.q_d=0\ and\ \frac{\partial\rho}{\partial t}+(v.\nabla)\rho=0 \quad (10)$$

Where M = $\frac{\in\tilde{N}}{N_0}$ and N_0 = initial uniform number density, Ñ = perturbations in number density and D = $\frac{d}{dz}$

In normal mode after analyzing the solutions whose dependency on x, y and t is govern by exp(ilx + imy + nt) (11)

where l, m be the horizontal wave number and $k^2 = l^2 + m^2$ while n is a complex constant.

With the help of perturbation equation (11), the equations (6) to (9) changes after eliminating q_d, we get

$$\left[n`+\frac{v+v`n}{k}-v(D^2-k^2)\right]\rho u=il\delta p \quad (12)$$

$$\left[n`+\frac{v+v`n}{k}-v(D^2-k^2)\right]\rho v=-im\delta p \quad (13)$$

$$\left[n`+\frac{v+v`n}{k}-v(D^2-k^2)\right]\rho w=-D\delta p-g\delta\rho \quad (14)$$

and

$$\in n\delta\rho=-wD\rho \quad (15)$$

ilu + i mv + Dw = 0 (16)

where $n` = \frac{n}{\epsilon}\left(1+\frac{mN_0K/\rho}{mn+K}\right)$

Eliminating δp between equation (12) to (14) and with the help of equation (15) and equation (16), we get

$$n`[D(\rho Dw) - k^2\rho w] + \left(\frac{1}{k`} - D^2 + k^2\right)[Dv(\rho Dw) - k^2 v\rho w] + \frac{n}{k`}[Dv`(\rho Dw) - k2v`\rho w = -gk2n\epsilon wD\rho \qquad (17)$$

3. VISCOUS AND VISCO ELASTIC (WALTERS B`) FLUIDS, SEPARATED BY A HORIZONTAL BOUNDARY

Let two uniform densities ρ_1, ρ_2 and uniform viscosities μ_1, μ_2. The boundary z = 0 is separated the system, so system is divided in to two regions. Since here densities, viscosities and viscoelasticities are uniform so we can take in each region the density ρ, viscosity μ and viscoelasticity μ` are constant. So equation (17) becomes

$$(D^2 - k^2)w = 0 \qquad (18)$$

Equation (18) is differential equation of second order, so general solution of equation (18) is

$$W = Pe^{+kz} + Qe^{-kz} \qquad (19)$$

Where P and Q are the arbitrary constants.

The current issue's boundary conditions are

(a) For upper layer fluid as z+ and lower layer fluid as z goes to-, the velocity should disappear.
(b) W (z) is continuous when z = 0.
(c) There are jumped conditions present at the interface.

Using the boundary conditions (a) and (b), we get

$W_1 = Pe^{+kz}$, (z < 0)

$W_2 = Qe^{-kz}$, (z > 0)

To ensure the continuity of w at z = 0, we have to take P = Q.

So we get

$$W_1 = P\,e^{+kz}, \quad (z < 0) \qquad (20)$$

$$W_2 = P\,e^{-kz}, \quad (z > 0) \qquad (21)$$

At the horizontal boundary z = 0, equation (17) gives the jump condition as

$$n`\nabla_0(\rho Dw) + \left(\frac{1}{k`} - D^2 + k^2\right)\Delta_0(\rho v Dw) + \frac{n}{k`}(\rho v` Dw) + \frac{gk^2}{n\epsilon}\Delta_0\rho w_0 = 0 \qquad (22)$$

With the help of condition (22) the solutions (20) and (21), reduces as

$$n^3\left[1+\frac{\epsilon}{k`}(\alpha_2 v`_2 + \alpha_1 v`_1)\right] + n^2\left[\frac{K}{m} + \frac{N_0K}{\rho_1+\rho_2} + \frac{\epsilon}{k`}(\alpha_2 v_2 + \alpha_1 v_1) + \epsilon k^2(\alpha_2 v_2 + \alpha_1 v_1) + \epsilon Kmk`\alpha 2v`2+\alpha 1v`1+\epsilon k2+s\pi d2(\alpha 2v2+\alpha 1v1)+n\epsilon Kmk`\alpha 2v2+\alpha 1v1+\epsilon k2Km\alpha 2v2+\alpha 1v1+\epsilon Kmk2+s\pi d2\alpha 2v2+\alpha 1v1+gk2\alpha 2-\alpha 1+gk2Km\alpha 2-\alpha 1=0 \qquad (23)$$

Where $\alpha_{1,2} = \frac{\rho_{1,2}}{\rho_1+\rho_2}, v_{1,2} = \frac{\boxed{?}_{1,2}}{\rho_{1,2}},\ v`_{1,2} = \frac{\boxed{?}`_{1,2}}{\rho_{1,2}}$

Certainly a stable instance exists for ($\alpha_2 < \alpha_1$).

The system is stable because equation (23), which forbids the emergence of a positive root, does not entail any sign shift.

ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 11, Iss 11, 2022

This is undoubtedly an unstable situation for ($\alpha_2 > \alpha_1$). Since equation (23), which has one positive root, has the term free from n, which is negative, it is permissible to have two roots with different signs. The system is unbalanced because a positive root exists.

4. EXPONENTIALLY VARYING DENSITY CASES:

We assume that the density stratification in the fluid of depth d` is

$$\rho(z) = \rho_0 e^{\beta z} \tag{24}$$

here constant are ρ_0 and β. let $\beta d` << 1$, Meaning that in the velocity field, the density fluctuation at two adjacent sites is substantially smaller than the average density, meaning that these have very little bearing on the fluid's inertia.

Then boundary conditions are for the scenario of two free surfaces.

$$w = 0,\ D^2 w = 0,\ at\ z = 0\ and\ \ z = d` \tag{25}$$

Equation (17) has solution which satisfying (25) is

$$w = w_0\, sin\frac{s\, sin\pi z}{d} \tag{26}$$

here constant is w_0 and s is an integer.

With the help of equation (26), (17) and neglecting the effect of inertia, we get

$$n^3\left[1+\frac{\epsilon v`}{k`}\right]+n^2\left[\frac{K}{m}\left(1+\frac{mN_0}{\rho}\right)+\frac{\epsilon v}{k`}+\epsilon v k^2+\frac{\epsilon v` K}{mk`}+\epsilon v\left\{k^2+\left(\frac{s\pi}{d`}\right)^2\right\}\right] + n\left[\frac{\epsilon v K}{mk`}+\frac{\epsilon v K k^2}{m}+\frac{\epsilon v K}{m}\left\{k^2+\left(\frac{s\pi}{d`}\right)^2\right\}-\frac{g\beta k^2}{k^2+\left(\frac{s\pi}{d`}\right)^2}\right]-\frac{g\beta K k^2/m}{k^2+\left(\frac{s\pi}{d`}\right)^2} = 0 \tag{27}$$

Equation (27) demonstrates that there is no positive root in stable stratifications ($\beta < 0$), indicating that the system is stable. The negative constant factor in equation (27), which is present in unstable stratifications ($\beta > 0$), permits roots of various signs, indicating that the system is unstable.

For convenience of calculation and without loss of generality, we can take the value of d` = sπ. The above equation (27) will change as

$$n^3\left[1+\frac{\epsilon v`}{k`}\right]+n^2\left[\frac{K}{m}\left(1+\frac{mN_0}{\rho}\right)+\frac{\epsilon v}{k`}+\epsilon v k^2+\frac{\epsilon v` K}{mk`}+\epsilon v\{k^2+1\}\right]+n\left[\frac{\epsilon v K}{mk`}+\frac{\epsilon v K k^2}{m}+\right.$$

$\epsilon vKmk2+1-g\beta k2k2+1-g\beta Kk2mk2+1=0$

(28)

We examine the natures of $\frac{dn}{dv}, \frac{dn}{dv`}, \frac{dn}{dN_0}, \frac{dn}{dk`}$ *and* $\frac{dn}{dK}$ analytically and graphically to find the role of viscosity, viscoelastisity, particle number density, medium permeability and drag coefficient taking the growth rates of unstable modes.

From equation (28) we get

$$\frac{dn}{dv} = n^2\left[2k^2+\frac{1}{k`}\right]+n\left[2\frac{Kk^2}{m}\right]+\frac{K}{k1m} \tag{29}$$

$$\frac{dn}{dv`} = \frac{n^3}{k`}+\frac{Kk`n^2}{m} \tag{30}$$

$$\frac{dn}{dN_0} = \frac{Kn^2}{\rho} \tag{31}$$

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 UGC CARE Listed (Group -I) Journal Volume 11, Iss 11, 2022

$$\frac{dn}{dk`} = -n^2\left[\frac{v}{k`^2} - \frac{kv`}{m}\right] - \frac{n^3 v`}{k`^2} - \frac{Kvn}{k`^2 m} \quad (32)$$

And

$$\frac{dn}{dK} = n^2\left[\frac{1}{m}\left\{\frac{N_0 m}{\rho} + 1\right\} + \frac{k`v`}{m}\right] + n\left[\frac{2K^2 v}{m} + \frac{v}{k`m}\right] - \frac{\beta g}{m} \quad (33)$$

5. RESULTS AND DISCUSSION

With the aid of the MATLAB programme, we can now examine the effects of viscosity, viscoelasticity, particle number density, medium permeability, and drag coefficient using graphical technique in order to display the stability characteristics.

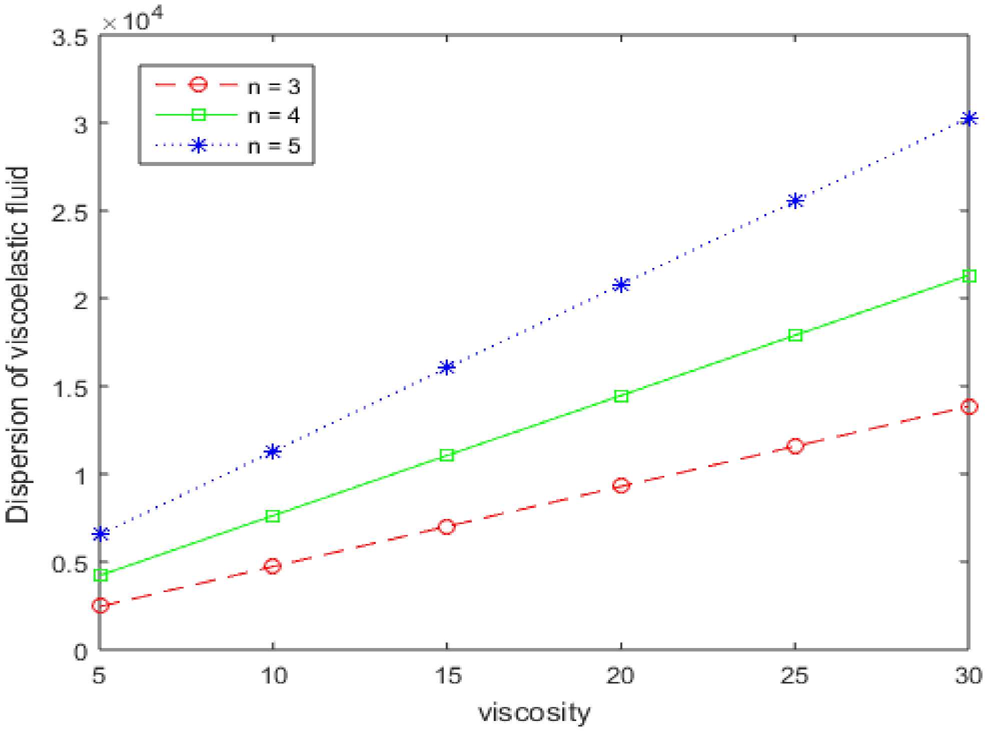

Fig 1 Graph plotted between viscosity and dispersion of viscoelastic fluid

In figure 1 the graph is obtain by taking v1=10; $\epsilon = 1$; $N_0 = 10$; K=0.5; $k_1 = 1$; $\rho = 7$; m=0.1; k=3; g=9.8; $\beta = 2$; for n=3, n = 4 and n = 5. From the graph we observe that as increase the value of viscosity the dispersion of viscoelastic fluid increases.

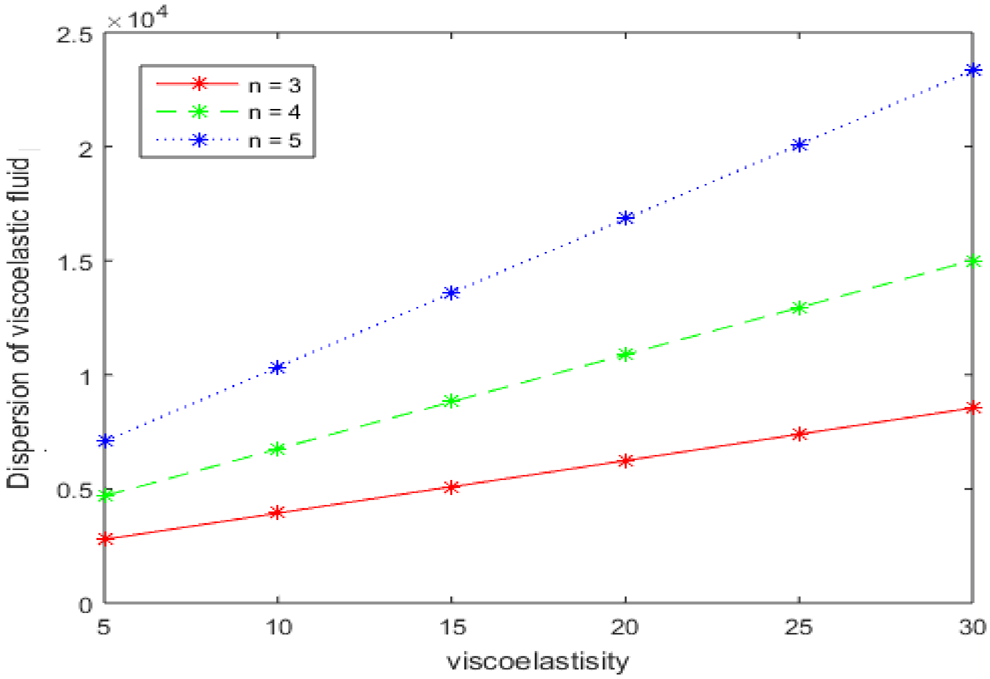

Fig 2 Graph plotted between viscoelastisity and dispersion of viscoelastic fluid

In figure 2 the graph is obtain by taking v = 5; ϵ = 1; N_0 =10; K=0.5; k_1=1; ρ=7; m=0.1; k=3; g=9.8; β=2; for n=3, n = 4 and n = 5. From the graph we observe that as increase the value of viscoelastisity the dispersion of viscoelastic fluid increases.

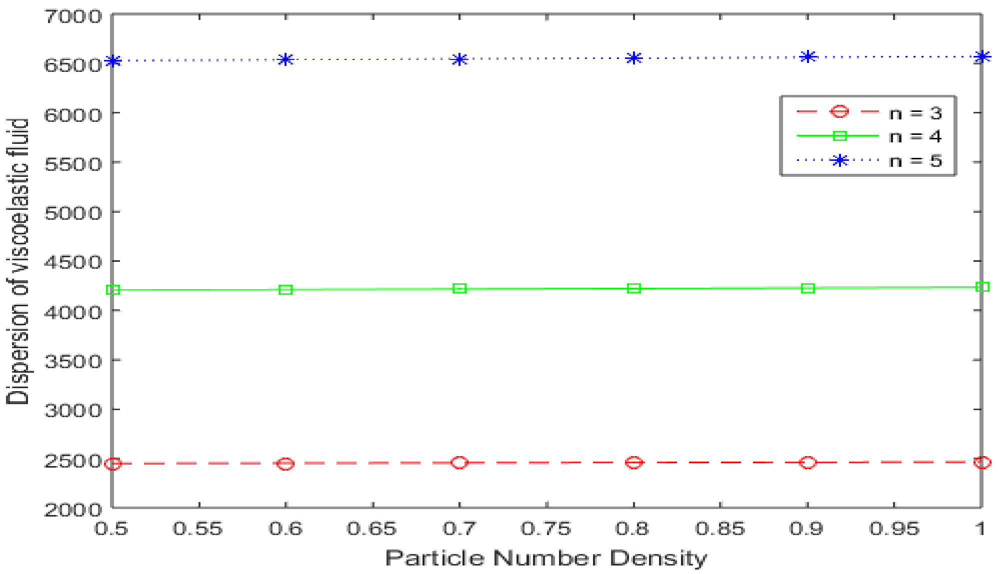

Fig 3 Graph plotted between Particle Number Density and dispersion of fluid

In figure 3 the graph is obtain by taking ϵ = 1; v1=10; v = 5; K= 0.5; k_1=1; ρ=7; m=0.1; k=3; g=9.8; β=2; for n=3, n = 4 and n = 5. From the graph we observe that particle number density does not affected the dispersion of viscoelastic fluid.

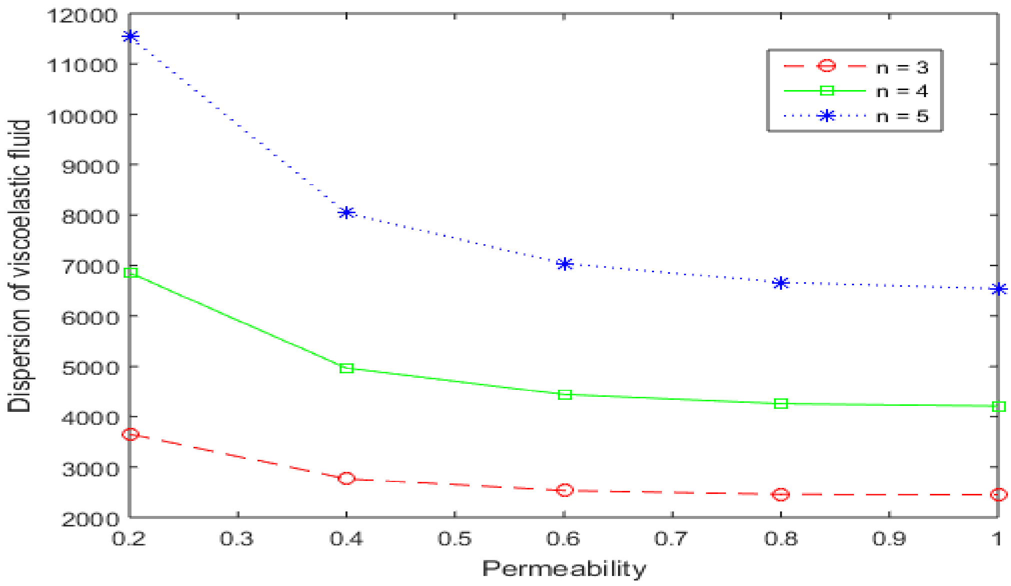

Fig 4 Graph plotted between Permeability and dispersion of viscoelastic fluid

In figure 4 the graph is obtain by taking v1=10; $\epsilon = 1$; $N_0 = 10$; K=0.5; v = 5; ρ=7; m=0.1; k=3; g=9.8; β=2; for n=3, n = 4 and n = 5. From the graph we observe that as increase the value of permeability the dispersion of viscoelastic fluid decreases.

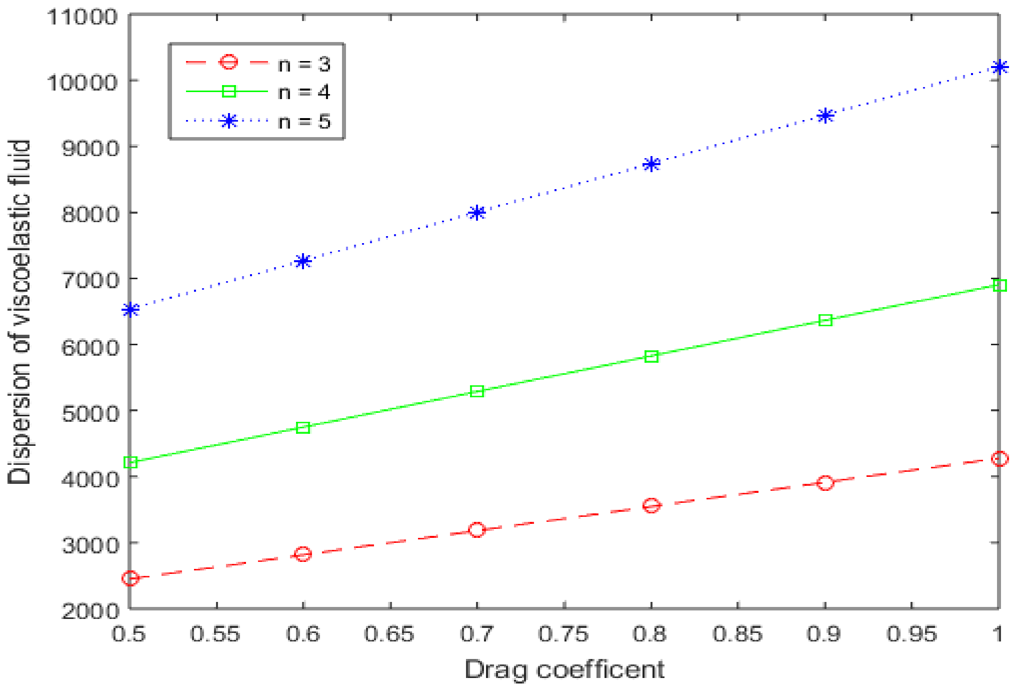

Fig 5 Graph plotted between Drag Coefficient and dispersion of viscoelastic fluid

In figure 5 the graph is obtain by taking $\epsilon = 1$; v1=10; $N_0 = 10$; v = 5; k_1=1; ρ=7; m=0.1; k=3; g=9.8; β=2; for n=3, n = 4 and n = 5. From the graph we observe that as increase the value of drag coefficient the dispersion of viscoelastic fluid increases.

ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 11, Iss 11, 2022

Equation (28) was differentiated to provide equations (29), (30), (31), (32) and (33). dn/dv, dn/(dv'), dn/(dN_0), dn/(dk'), and dn/dK may be positive or negative, according to our analysis. This suggests that for the unstable stratification, growth rates both fall (for some wave numbers) and increase (for different wave numbers) as particle number density and medium permeability increase.

6. CONCLUSION:

In the present study, we discussed the stability of two superposed viscoelastic fluids. We look into the problem of particles suspended in a porous medium. After discussing both stable and unstable circumstances, a formula is created (23). Additionally, the case of exponentially varying density $\rho(z) = \rho_0\, e^{\beta z}$, is taken into consideration in our analysis. The system's stability for stable stratifications ($\beta < 0$) and instability for unstable stratifications ($\beta > 0$) were examined. From the graph, we inferred that fluid dispersion rises with fluid viscosity, viscoelastism, and drag coefficient, whereas it falls with fluid permeability. The density of the particles has no impact on the fluid's dispersion. The fact that all the terms in equations (29), (30), and (33) are positive rather than negative serves as proof for the aforementioned assertion. All of the variables in equation (31), which are constant in our study and do not alter the dispersion, are constant.

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